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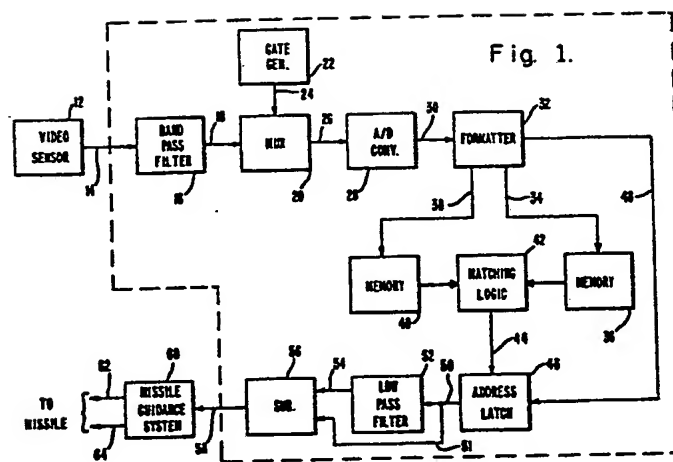
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(54) Jitter compensated scene stabilized missile guidance system.

(57) An improved missile guidance system is provided which automatically compensates for jitter motion of the optical sight of a video tracker. The invention is adapted to receive video data input from an infrared detector or conventional camera (12). The invention includes circuits for filtering, gating, and digitalizing the incoming data as well as a formatter for directing successive frames into memory. Two memories (36, 40) are provided; the contents of which are sampled by matching logic (42) as the second memory is being loaded. The matching logic (42) thereby compares one frame of data to another at plurality of positions and provides a signal to an address latch (46) when the best match is obtained. The format circuitry (32) provides the position information to the address latch where it is stored for further processing. The output of the address latch is filtered to eliminate any signals representative of intentional tracking motion. The filtered output thus provides the jitter correction to the missile guidance system (60) where missile guidance signals are compensated by the jitter correction.

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JITTER COMPENSATED SCENE STABILIZED
MISSILE GUIDANCE SYSTEM

1 BACKGROUND OF THE INVENTION

1. Field of the Invention

5 This invention relates to missile guidance systems. More specifically, this invention relates to improvements in the guidance of line-of-sight commanded missiles.

10 While the present invention is described herein with reference to particular embodiments and applications, it is to be understood that the invention is not limited thereto. Modifications may be made within the teachings of this invention without departing from the true spirit and scope thereof.

2. Description of the Prior Art

15 A typical line-of-sight guided missile system includes a launcher and a guided missile. The launcher typically includes a gunner's optical sight and an electronic guidance computer which automatically sends steering commands to the missile in flight. After launch, a beacon in the tail of the missile is activated and subsequently detected by a sensor on the launcher.
20 The sensor is bore sighted with the gunner's telescope, and allows the operator to track the missile along its flight path. The sensor and associated processing circuitry measures the angle between the flight direction of the missile and the gunner's line-of-sight. These
25 displacements are transformed by a computer into guidance commands which are sent to the missile over

1 the command link. The gunner need only keep the cross-hairs of the sight on the target during missile flight.

Unfortunately, in an actual hostile operational environment, the operator may experience nervous
5 jitters which would tend to impair his ability to maintain the cross-hairs on the center of the target's most vulnerable aim point. If the operator jitters the sensor line-of-sight, the missile tracker would measure a corresponding apparent missile off-set. As it corrected
10 the nonexistent off-set, it would create perturbations which would appear as noise in the missile guidance signals. This would detract from the hit-accuracy of the guidance and tracking system.

15 SUMMARY OF THE INVENTION

The present invention provides means for improving the performance of line-of-sight commanded missile guidance systems.

The present invention utilizes a video sensor for
20 providing successive frames of data corresponding to at least a portion of a video scene as viewed by the operator through an optical sight. Signal processing circuitry is provided for analyzing the frames of data to provide electrical signals indicative of the
25 jitter motion of the optical sight relative to stationary objects in the video scene.

More specifically, the present invention includes means for converting information representative of the video scene into a train of discrete signals. Successive
30 frames of discrete data are then compared on a pixel by pixel basis until a best match is obtained. (A "pixel" is an individual picture element.) The address at which the best match is obtained provides information indicative of the jitter motion of the tracking system. (The "address"
35 is the reference in number of rows and columns in each frame.) Data must be successively displaced to achieve

- 1 the best match to a prior frames reference (or address)
This information is then utilized to off-set the jitter
motion effect on the missile guidance signals.

5 BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic representation of a
preferred embodiment of the invention.

FIG. 2 is representative of the processing of a
first frame of video data by the system of the present
10 invention.

FIG. 3 is representative of the processing of a
second frame of video data by the system of the present
invention.

FIG. 4 illustrates the method by which successive
15 frames of data are compared by the system of the present
invention.

DETAILED DESCRIPTION OF THE INVENTION

This invention substantially eliminates the
20 effect of gunner jitter by initially tracking
arbitrary portions of the background of a video
scene remote from the target. The basis for
estimating the gunner jitter is the apparent motion
of the stationary scene. By measuring how elements
25 of the scene, remote from the target, appear to be
moving, gunner jitter may be estimated. The estimation
is represented by electrical signals which are sub-
tracted from the missile guidance signals so that
the normally occurring gunner jitter is suppressed.

30 FIG. 1 shows a block diagram representing
of a digital system designed to suppress gunner
jitter. It should be noted that while a digital
system is disclosed, the principals of the present
invention may be realized through equivalent analog
35

1 circuitry. The gunner jitter suppression circuit is shown
at 10 in FIG. 1. The suppression system 10 is adapted to
receive video data from a video sensor 12. The video
sensor 12 may be a forward looking infrared (FLIR) sensor
5 or an electronic T.V. camera. The video sensor block
would also include a display and/or an optical sight
through which the operator may view the video scene. The
video output of sensor 12 appears on line 14 and is input
to the bandpass filter 16. The bandpass filter 16 is
10 effective as a differentiator to transform the video data
so that subsequent correlations may be more easily
measured and identified. The effect of differentiation
is to delineate scene boundaries. The processing scheme
of the present invention utilizes boundary change infor-
15 mation to estimate gunner jitter.

The output of the bandpass filter 16 provides
one input to a multiplexer 20 via line 18. The second
input to the multiplexer 20 is provided by the gate
generator 22 via line 24. The multiplexer 20 and
20 gate generator 22 operate on the analog video output
of the filter in such a way as to pass data representing
portions of the video scene remote from the center
of the field of view. Thus, gated video appears at
the output of multiplexer 20 on line 26 and is input
25 to an analog-to-digital (A/D) converter 28.

The A/D converter 28 thresholds the video data
to produce a mosaic of 1's and 0's. See FIGS. 2 and
3. This stream of binary video is input to a formatter
32 via line 30. The formatter 32 directs video data
30 into a first memory 36 via line 34 until a first
frame of gated video is stored. Similarly, video
data is subsequently formatted into a second memory
40 via line 38.

1 FIGS. 2 and 3 illustrate the processing of the data
up to this point. FIG. 2a shows that the first frame of
data appears at the output of video sensor 12 as raw video.
The upper portion of the figure illustrates a portion of a
5 typical video scene with the background clutter represented
as a shaded area. The filtered video for the corresponding
line of data is represented in the lower portion of the
figure as a pulse two units wide.

 FIG. 2b is illustrative of the same video bandpassed
10 by filter 16. The upper portion of the figure now shows
the boundaries as shaded areas while the lower portion of
the figure is representative of the derivative of the pulse
in FIG. 2a.

 FIG. 2c shows the same portion of the video scene
15 at the output of the analog-to-digital converter 28.
Shaded portions are represented by 1's; the remaining
portions are represented by 0's. FIG. 2c is thus a mosaic
of 1's and 0's. Formater 32 provides the formatted video
of frame 1 to memory 36 in a format typified in FIG. 2d.

20 FIG. 3 illustrates that the second frame of data
corresponds to a jitter motion effective to displace the
sensor one element to the left. Note that the raw video
of FIG. 2a is now moved to the right by one unit as illu-
strated in FIG. 3a. Subsequent filtering, digitalizing,
25 and formatting, in the manner described above, yields a
displacement of one unit to the right of the 1's in the
data stream associated with line 3 of FIG. 3d.

 Video detector 12, bandpass filter 16, multiplexer
20, gate generator 22, analog-to-digital converter 28,
30 and formator 32 thus provide successive frames of video
data for processing in the manner described below.

 Returning now to FIG. 1, the information
stored in memories 36 and 40 is compared by matching
logic 42. The matching logic may be provided
35 by a computer or other digital or analog circuitry.

1 After frame 1 is loaded in memory 36, matching logic
42 samples frame 2 as it is being formatted into memory.
The data in memory 40 is sampled and compared at every
step or pixel. The location which gives the best overall
5 match is referenced to the last frame's location in order
to compute incremental motion. The process is illustrated
in FIG. 4.

FIG. 4a shows that at position N-1 there are 21
pixels which match and 4 pixels which do not match. The
10 X's indicate "don't cares". FIG. 4b illustrates that the
data has marched one position in time to where the number
of matches is 25. FIG. 4b thus illustrates position N.
FIG. 4c illustrates position N+1 where the number of
matches is once again 21. Position N therefore provides
15 the best match and indicates the displacement of the scene
due to gunner jitter to be one pixel to the left.

When matching logic detects the best match, it
signals address latch 46 via line 44. At that point the
address latch interrogates the formatter 32 to determine
20 and store the position at which the best match is obtained.
This information appears on line 48. The address latch 46
thus provides on line 50 information containing the jitter
for say the i th sample or J_i .

Memories 36 and 40, matching logic 42, and address
25 latch 46 thus provide means for analyzing successive
frames of video data to provide signals indicative of
jitter motion of the tracker relative to the video scene.

What remains is to determine whether the incre-
mental motion is in fact jitter motion or tracking
30 motion. That is, scene stabilization must be selective.
It must reduce effects of operator jitter while permit-
ting accurate tracking of moving targets. Low-pass
filter 52 and subtractor 56 serve to provide this
function. The solution to this problem as afforded

1 by the low-pass filter 52 and the subtractor 56 is
best illustrated by Equation 1.

$$5 \quad [1] \quad C_i = J_i - \frac{\sum_{x=i-n}^i J_x}{n}$$

Where C_i is the i th correction corresponding
to the i th frame and J_i is the i th jitter sample.
Equation 1 illustrates that the jitter correction
10 C for a given frame i is equal to the difference
between the incremental jitter sample J_i and the

average of the previous n jitter samples $\frac{\sum_{x=i-n}^i J_x}{n}$.

15 Address latch 46 provides J_i to low-pass filter
42 via line 50 and to subtractor 56 via line 51. Low-
pass filter 52 provides the average of the previous
jitter samples to the subtractor on line 54. The output
20 of the subtractor on line 58 is the correction C for a
frame i .

Equation 1 can be verified functionally when one
considers that in a situation where the gunner is in
fact causing the tracker to undergo jitter, the effect
25 of the jitter maybe sinusoidal in nature. As a result,
its average would be zero and the correction would equal
the i th jitter sample. However, when the operator is
tracking a target, the tracker position does not vary as
a sinusoid but more as a ramp. The average behavior of
30 a filtered ramp is another ramp delayed in time. Thus
the corresponding correction would be the jitter which
rides on the ramp. The filtered ramp is subtracted from
this to leave a small value relative to the missile
guidance signals.

1 It should be noted here that the solution to the
jitter/tracking ambiguity of FIG. 1 is illustrative of but
one of several possible approaches to the problem. Another
approach would be to utilize a high-pass filter to simply
5 filter out the signals corresponding to the low frequency
tracking motion of the tracker. Yet another approach
would be to utilize an algorithm implemented by a micro-
processor such as that which may be provided by the missile
guidance system 60. The use of the low-pass filter and
10 subtraction technique is preferred in so far as low-pass
filters appear to function better as integrators than
high-pass filters function as differentiators.

 The correction signal C is ultimately provided
to the missile guidance system 60 via line 58 where
15 it is subtracted from the missile guidance commands
appearing on line 62 and 64.

 Thus, the low-pass filter 52, subtractor 56 and the
missile guidance system provides means for compensating
the missile guidance signals as a function of the jitter
20 correction signals to provide signals for effectively
guiding the missile notwithstanding jitter motion of the
tracker.

 The present invention has been described with refer-
ence to a particular embodiment and a particular appli-
25 cation. It is contemplated that modifications may be
made by those having ordinary skill in the art and access
to the teachings disclosed herein which are encompassed
within the principles of this invention. For example,
systems which include image intensifiers, scan converters,
30 or vidicons can be adapted to use this same correction
technique for image-motion compensation. It is thus con-
templated by the appended claims to cover any and all such
modifications and applications.

CLAIMSWhat is Claimed is:

- 1 1. In a missile guidance system including
tracking means and means for providing first signals
for guiding a missile to a target, an improvement
comprising:
 - 5 means for providing successive frames
of data corresponding to at least a portion of a
video scene as viewed by said tracking means;
 means for analyzing said frames of data
and providing second signals indicative of jitter
10 motion of said tracking means relative to said
video scene; and
 means for compensating said first signals
as a function of said second signals to provide
signals for effectively guiding said missile not-
15 withstanding any jitter motion of said tracking means.
- 1 2. The missile guidance system of Claim 1
wherein said means for providing successive frames
of data corresponding to a video scene includes
detector means for detecting optical energy and
5 providing a corresponding electrical output and
means for storing said successive frames of data.
- 1 3. The missile guidance system of Claim 1
wherein said means for analyzing successive frames
of data includes means for correlating successive
frames of data and means for storing an electrical
5 signal representative of incremental motion of
said tracking means when successive frames
correlate.

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1 4. The missile guidance system of Claim 1
wherein said means for compensating said first signals
includes means for discriminating between jitter
noise and tracking signals.

1 5. The missile guidance system of Claim 4
wherein said means for discriminating between jitter
noise and tracking signals includes means for
averaging the output of said means for storing an
5 electrical signal representative of incremental motion
of said tracking motion means and means for subtracting
said average from the instantaneous output of said means
for storing electrical signal representative of the
incremental motion of said tracking means.

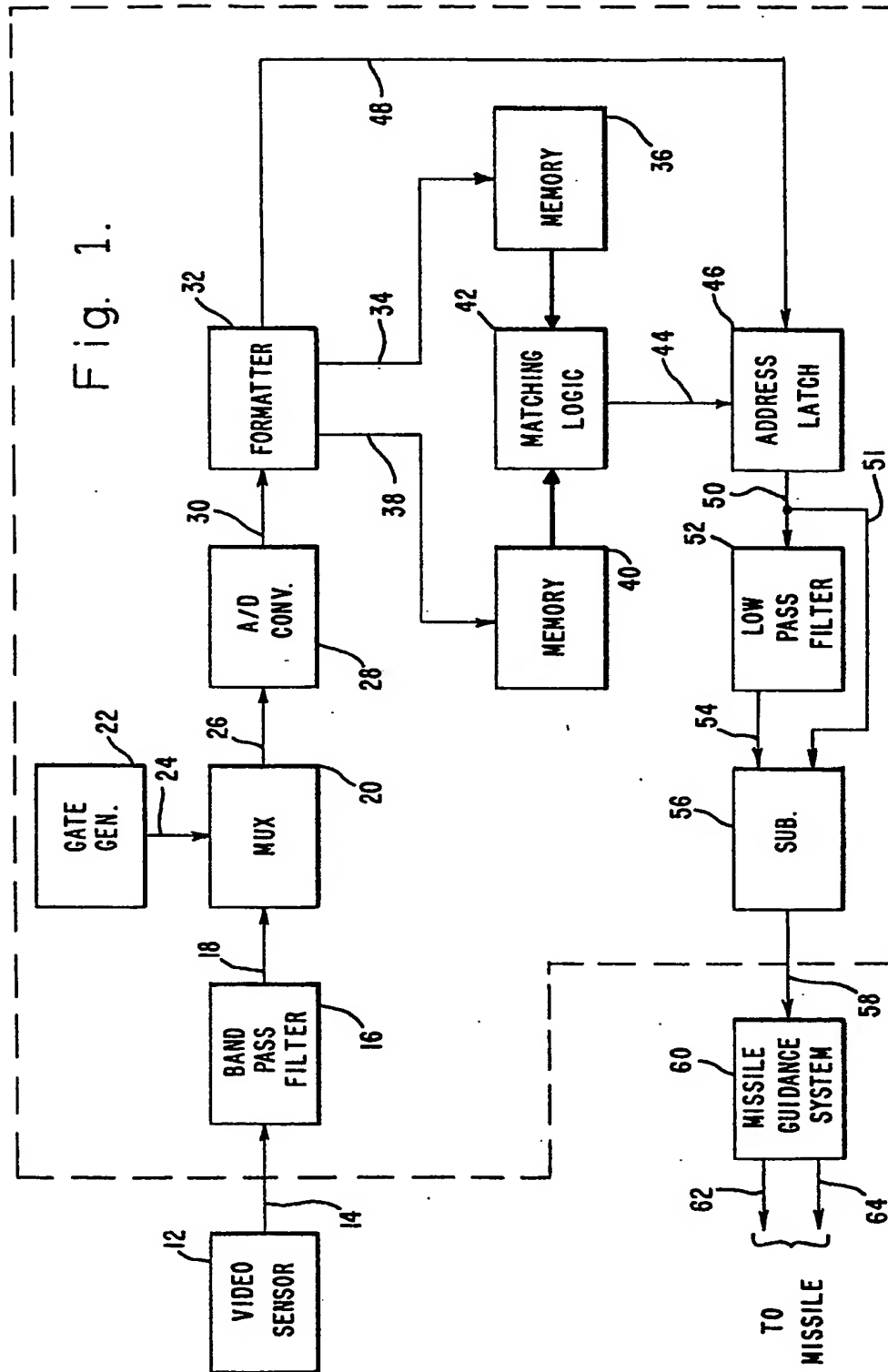
1 6. A missile guidance system comprising:
 means for detecting optical energy and
providing video data;
 first filter means for differentiating
5 said video data to provide filtered output signals;
 gating means for selecting predetermined
filtered output signals to provide a gated output;
 converter means for transforming said
gated output to digital signals;
10 means for forming said digital signals
to provide successive frames of video data;
 means for storing said successive frames
of video data;
 means for comparing said successive frames
15 of video data at a plurality of relative positions to
provide an electrical signal indicative of the position
at which said frames provide a maximum correlation;

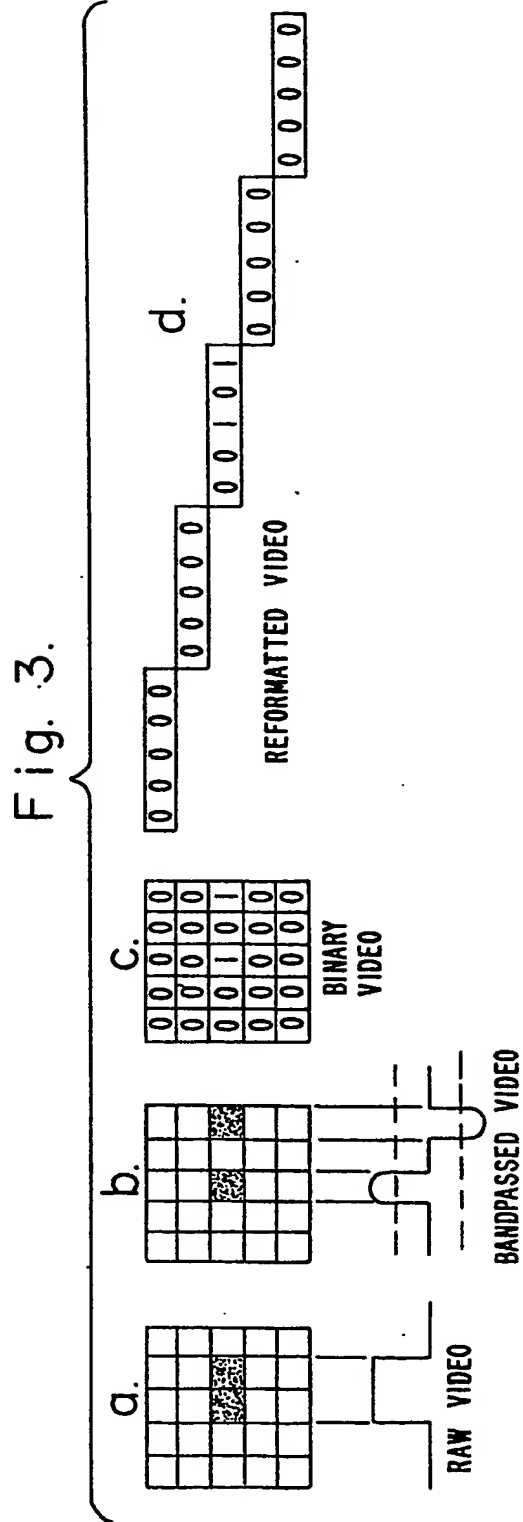
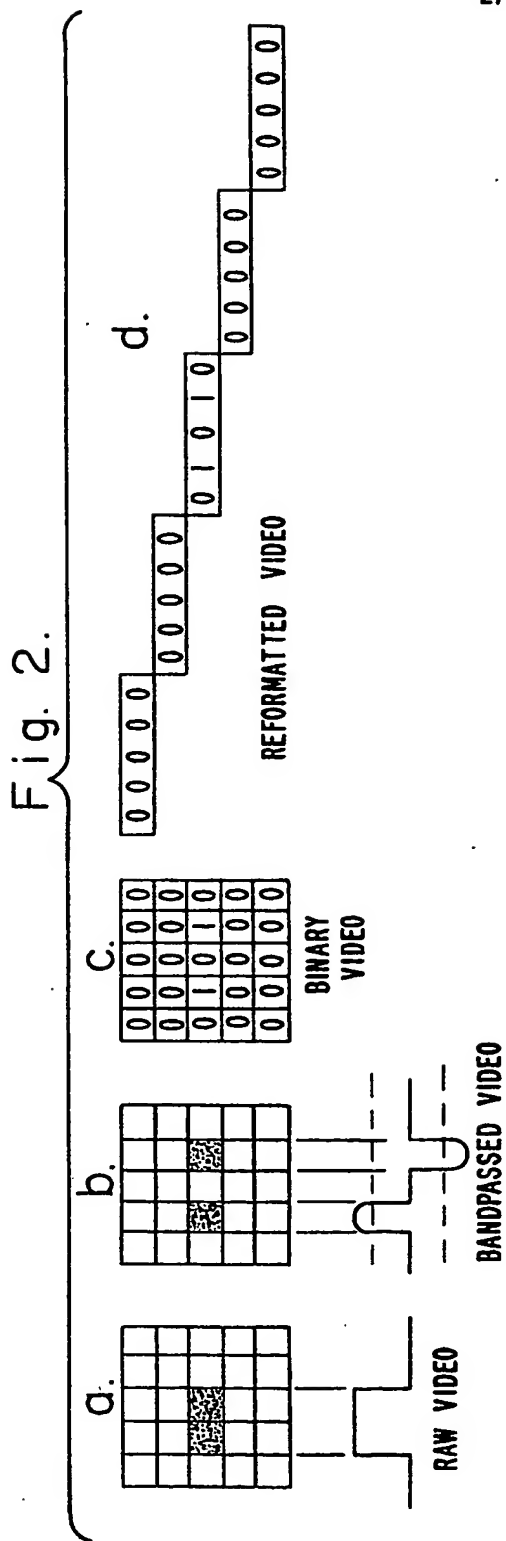
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means for storing said electrical signal
corresponding to the position at which said frames
20 provide a maximum correlation to provide an electrical
signal indicative of the incremental motion of said
means for detecting optical energy;

means for processing said electrical
signal corresponding to incremental motion of said
25 means for detecting optical energy to discriminate
between signals corresponding to jitter motion and
signals corresponding to tracking motion; and

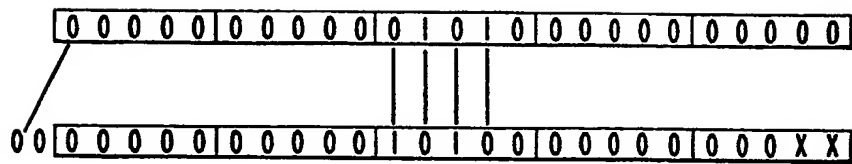
means for compensating missile guidance
signals to correct for noise resulting from jitter
30 motion of said means for detecting optical energy.



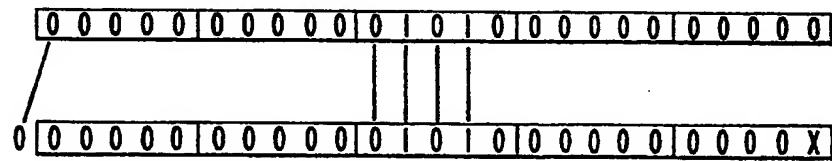


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a.



b.



c.

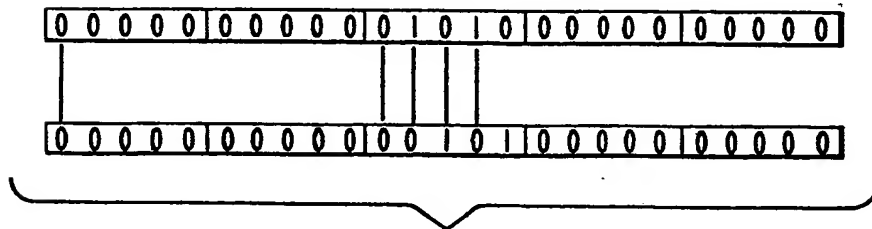


Fig. 4.



European Patent
Office

EUROPEAN SEARCH REPORT

0064168

Application number

EP 82 10 2966

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 7)
Y	US-A-4 247 059 (J.R.DUKE et al.) *The whole document*	1-6	F 41 G 7/30
Y	US-A-4 220 967 (L.F.ICHIDA et al.) *Column 1, line 20 to column 2, line 5; column 3, line 4 to column 4, line 20; figure 1*	1-6	
A	US-A-3 233 847 (A.GIRSBERGER) *The whole document*	1,4,5	
A	US-A-3 274 552 (G.L.HARMON et al.) *The whole document*	1,4,5	
A	GB-A-1 299 851 (BRITISH AIRCRAFT CORP) *Page 1, lines 51-61*	1	TECHNICAL FIELDS SEARCHED (Int. Cl. 7) F 41 G G 01 S
A	US-A-3 829 614 (S.H.AHLBOM et al.)		
A	US-A-3 885 453 (H.P.HIGGINSON et al.)		
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 10-08-1982	Examiner VAN WEEL E.J.G.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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